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# Demand side management in India: Action plan, policies and regulations

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ABSTRACT

The paper introduces the approach and concept for DSM in India. A comprehensive methodology for implementing a DSM programme in India has been outlined. Detailed step wise action plan formulated for planning and implementing of DSM programme in India is presented. Various policies and regulations framed by India for promotion of DSM activities targeting different sectors are studied. The deficiencies in the existing regulatory and policy framework which have withheld deployment of DSM programmes on a large scale in India have been identified. A number of barriers and challenges that are needed to overcome for realizing the potential of DSM in India are also discussed.



**Contents**



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## 1. Introduction

India is home to more than 17% of the world's population [1], with a rapidly growing economy at an annual rate of 8–9% [2]. India is the fourth largest energy consumer in the world after the United States, China, and Russia [4] and is poised to become the world's third largest economy by 2030, only after China and United States [3]. It has the fifth largest electricity grid in the world [7] and the world's third largest transmission and distribution network [8].

India's power industry is facing challenges of supply shortfalls, high T&D losses, power theft, and inefficiency in metering and revenue collection. India's transmission and distribution losses are of very high magnitude in the world, averaging 26% of total electricity production. Taking into account energy theft, total losses are as high as 50% [9].

### 1.1. Electric power scenario in India

Over the years, India has achieved a steady increase in its electric power installed capacity. However, growth in demand for electric power has outweighed the growth in installed capacity, which has led to a situation of energy and peak shortages of 9.3% and 10.6%, respectively during 2012–13 [10]. The peak demand and energy deficits of India from 2007–08 to 2012–13 is shown in Table 1 [63].

Increased demand is directly related to the per capita consumption of electricity which is shown in Fig. 1, over a period of 8 years.

In order to reduce the gap between the demand and supply of electricity in India, adequate actions or measures are taken to manage electric power both at the supply side and also at the demand side. Supply side measures include building new power plants, reducing T&D losses, diversifying fuel-mix, energy storage technologies, thermal storage and so on [11]. The total installed capacity for electricity generation in India rose from 112 GW as on March 2004 to 229 GW as on December 2013 [5,12]. Capacity additions require high capital investments, timely approvals to build new power plants and there has been increasing inflation problem and decreasing availability of capital [13,55,56]. The growth of installed capacity since 6th five year plan (i.e., 31.03.80–31.03.85) is shown in Fig. 2.

An increase in electricity supply has a substantial tax revenue benefit to the government [14]. But adequate revenue collection by the electric utilities to cover their costs of supply is lacking as large

**Table 1**
Peak demand and energy deficit in India for last five years [63].

| Period | Peak demand (MW) | Peak met (MW) | Peak deficit/ surplus (%) | Energy requirement (MU) | Energy availability (MU) | Energy deficit/ surplus (%) |
|---|---|---|---|---|---|---|
| 2007–08 | 108,866 | 90,793 | −16.6 | 739,343 | 666,007 | −9.9 |
| 2008–09 | 109,809 | 96,785 | −11.9 | 777,039 | 691,038 | −11.1 |
| 2009–10 | 119,166 | 104,009 | −12.7 | 830,594 | 746,644 | −10.1 |
| 2010–11 | 122,287 | 110,256 | −9.8 | 861,591 | 788,355 | −8.5 |
| 2011–12 | 135,453 | 123,294 | −9.0 | 995,500 | 908,574 | −8.7 |
| 2012–13[a] | 149,619 | 136,312 | −8.9 | 1,129,609 | 1,028,993 | −8.8 |

[a] Anticipated.

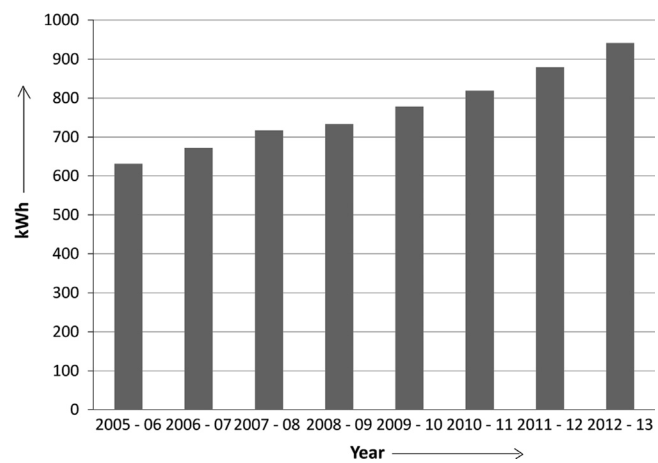


**Fig. 1.** Growth of per capita consumption of electricity [63].

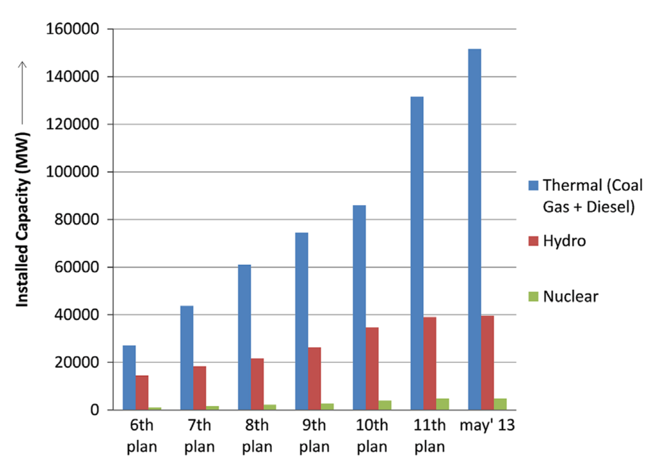


**Fig. 2.** Growth of installed capacity upto 2013 [63].

**Nomenclature**

| | |
|---|---|
| CHP | combined heat and power |
| DSM | demand side management |
| SG(s) | smart grid(s) |
| IRP | integrated resource planning |
| DG | distributed generation |
| ESCO(s) | Energy Service Company(s) |
| RE | renewable energy |
| MW/GW | mega watt/giga watt |
| kWh | kilo watt hour (energy unit) |
| SEB | State Electricity Board |
| EE | energy efficiency |
| BEE | Bureau of Energy Efficiency, India |
| CC | customer cost |
| TC | technology cost |
| FC | financing cost |
| SC | support cost |
| UC | utility cost |
| TrC | transaction cost |
| TRC | total resource cost |
| MoP | Ministry of Power |
| GoI | Government of India |
| BIS | Bureau of Indian Standards |
| PEM | proton exchange membrane (fuel cell) |
| MoU | Memorandum of Understanding |
| SDA | State Designated Agency |
| EM & V | Evaluation, Measurement and Verification |

investments are required for capacity additions and for transmission and distribution and also due to lack of access to capital and limited recovery of revenue [15]. Under such a scenario, utilization of electricity in an efficient manner can be a cheaper alternative to provide reliable electric power service.

Demand side measures include activities affecting customer's behavior of electricity consumption with the aim to change the load curve profile, developing energy efficient appliances and equipments, promoting energy conservation measures and so on.

DSM has been recognized an integral constituent of operational planning for an electric utility. A particular DSM programme activity is designed to encourage customers of different target sectors such as appliances, buildings, industries, etc, to modify their electricity usage patterns, timing and level of electricity demand. International [16–18] and quite a few of the Indian experiences [19,20] confirm that DSM can assist in regulation of electricity consumption and operational measures can substantially improve the productivity of existing electricity assets.

### 1.2. *Concept of demand side management*

The term demand-side management is the result of a logical evolution of planning processes used by the utilities in United States in the late 1980s [21]. India's Ministry of Power (MoP) specifies, "*Demand Side Management is used to describe the actions of a utility beyond the customer's meter, with the objective of altering the end-use of electricity – whether to increase demand, decrease it, shift it between high and low peak periods, or manage it when there are intermittent load demands – in the overall interests of reducing utility costs*" [22].

DSM covers several objectives, including that of load management and energy efficiency [57].

#### 1.2.1. *DSM with integrated resource planning and distributed generation*

Since the mid-1980s, DSM has been an important element of the electric utility planning approach referred to as Integrated Resource Planning (IRP) [23]. A very important part of the DSM process involves the consistent evaluation of demand-side to supply-side alternatives and vice versa. This approach is referred to as IRP [24]. Many successful examples of IRP and DSM exist throughout the world [25–27].

DSM creates opportunities and encouragement for the development of distributed generation (DG) technologies which involves energy generation cascade utilization in the demand side leading to optimal utilization of resources, renewable energy and energy storage technology [28]. DG is a technology set of decentralized generating resources located close to the site of energy demand or load [58]. To deal with capacity constraints of transmission and distribution systems, utilities around the world have started to consider alternative approaches [29]. Generation from distributed energy sources, such as photovoltaics, fuel cells, or batteries have been one of the commonly used approach [30,31]. Other approach is to reduce demand using DSM programmes in the targeted areas [32]. Decentralized power generation close to the rural load centers has the potential of addressing the energy crisis facing India [59].

Investing in IRP programmes which incorporate DG and DSM can help to reduce utility's variable costs and defer capacity investments [60] as illustrated in Fig. 3. At the end-point level the individual energy consumer can apply many of these same technologies with similar effects. One DG technology frequently employed by end-users is the modular internal combustion engine [33].

Among renewable options for DG, wind energy is growing significantly because of the supportive policy environment [34]. Solar PV, though highly variable in kWh production, has now become a viable option for grid connected systems in India. For isolated systems, hybrid energy systems of PV–wind–diesel can be cost-effective, though not yet implemented anywhere in India [34]

#### 1.2.2. *SG and DSM*

SG encompasses the integration of power, communications and information technologies for an improved electric power infrastructure that serves loads while providing for an ongoing evolution of end-use applications [35]. SG [36,37] facilitates electricity supply to the consumer in a smart way [38] through integration of sophisticated sensing and communication technologies and

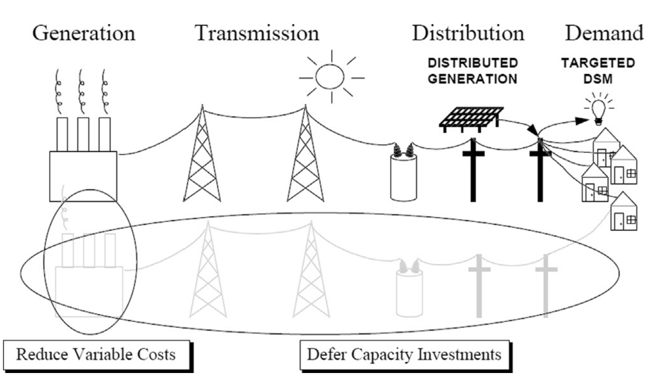


**Fig. 3.** Reduction of costs and capacity investments by SG and DSM [59].

advanced control methodologies at transmission and distribution levels [54].

DSM [39,40] is an important function in energy management of the future SG [38], providing support towards SG functionalities in various areas such as electricity market control and management, infrastructure construction, and management of decentralized energy resources and electric vehicles [41].

The remainder of the paper is organized as follows. Section 2 presents the overview of DSM programme action plan of India. DSM related Policies and regulations prevailing in India are discussed in Section 3. Barriers that are hampering the implementation of DSM programmes and the challenges to be addressed are presented in Section 4. Status and the defects of the developed action plan are discussed in Section 5. Section 6 concludes the paper.

## 2. DSM in India

Utilities in India have recognized DSM as an integral constituent of their operational planning. Utilities have designed DSM programmes to encourage customers alter their habit of electricity usage to make the load as consistent as possible. DSM programmes have been designed with a view of changing both the timing and the magnitude of utilization of electricity. Exercising of such an activity proves to be beneficial and cost effective, thereby maximizing productivity of utilities' resources. Consumers benefit by having better control on the usage of electricity and thus on the kWh costs. A comprehensive methodology for implementing a DSM programme, with a sole objective to influence the demand for the mutual benefit of the utility and the customer is presented here.

### 2.1. Planning and implementation strategy

Basically, utility is responsible for planning and developing DSM programme implementation strategy. However, other implementers include government organizations and regulators, profit as well as non profit groups, or a collaboration of different stakeholders may also be involved in the development of DSM programme planning and implementation strategy. Utilities, in India are bounded to provide reliable supply of electricity to the consumers at minimal costs.

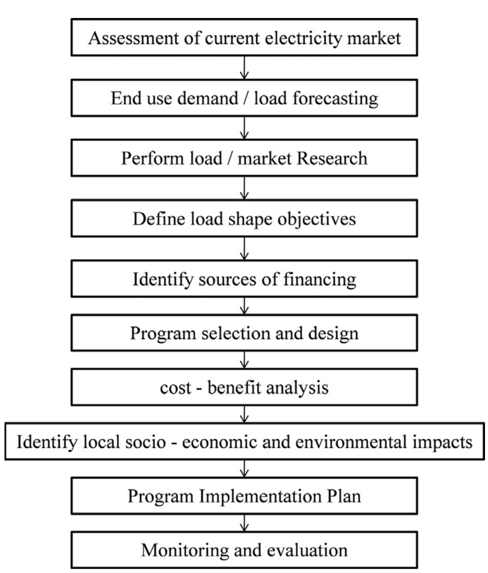


**Fig. 4.** Flowchart of the action plan for implementing a DSM programme in India.

With an objective of reduction of energy intensity in the Indian economy and to develop energy conservation and energy efficient programmes in India, Bureau of Energy Efficiency (BEE) was set up under the Ministry of Power (MoP) in March 2002 under the provisions of the India's Energy Conservation Act, 2001. BEE acts as a nodal agency for formulating an action plan for setting up of a DSM programme in India. Various steps that are followed by Indian utilities for implementing a particular DSM programme are shown in Fig. 4.

Each of the steps shown in Fig. 4 are described in detail below.

#### 2.1.1. Assessment of current electricity market

Preliminary information about the utility's current situation is assessed. The data generated during the assessment reflects the current status, performance and operational costs of the utility which serves as a benchmark for comparing the advantages and costs of alternative solutions incorporating DSM programmes. Information such as the growth perspectives for prices and fossil fuel supply conditions for power stations, portion of electricity generation through independent sources, annual rate of electricity exported/imported, efficiency of metering and billing systems, losses in transmission and distribution networks and in the electro-mechanical equipment, etc are the subjects to be considered during DSM planning.

#### 2.1.2. End use demand/load forecasting

Mid-term and long-term forecasts of variations in power demand are significant in planning and development of a DSM programme. In situations where such forecast data are not available, these are prepared at the beginning of the DSM programme planning activity after conducting a preliminary research about the utility's situation in the electricity market along with appropriate exercising of demand forecasting. Such a forecasting scheme involves inclusion of the following aspects of load:

- Sector-wise (residential, industrial, commercial, municipal, agricultural, and transport) estimation of electricity consumption and peak demand to derive load curves of each sector and in specific times, of end-use.
- Calibration of the consumption and peak demand to macro-economic variables (households, industrial output, floor space, etc.) using estimates of the efficiency of the current technologies used to meet each end-use.
- Estimation of future electricity consumption and peak demand by separately changing macro-economic variables, stock-turnover and additions, fuel share and end use technology efficiency.

#### 2.1.3. Load/market research

For an effective DSM programme, it is important to know trend of electricity consumption by the end user and to what extent of efficiency is being attained at that use. Load research involves the collection and analysis of the load data (system location, customer class, time, magnitude, etc), collected from different locations of the distribution system. Major sectors of interest to DSM programmes include the residential, commercial, industrial, municipal, agriculture and transportation (majorly railways) sectors.

Identifying the barriers and evaluating their possible solutions, market research is necessary to be carried out through customer survey. Such surveys can be used to determine equipment and appliance usage, decision making criteria, and views on different types of programmes. It is also important to carry out a survey of local manufacturers and suppliers to assess the availability of efficient products and services and their manufacturers.

#### 2.1.4. Define load shape objectives

After forecasting the demand and gaining enough knowledge about the way electricity is being consumed; the DSM planner specifically selects and defines a load shape objective, depending about the prevailing utility's situation. Although there can be infinite combination of load-shape-changing possibilities [44] the most commonly used patterns globally have been illustrated in Fig. 5. Such patterns are peak clipping, valley filling, load shifting, strategic conservation, strategic load growth, and flexible load shape. These are not mutually exclusive, and may frequently be employed in combinations.

Techniques of peak clipping, valley filling and load shifting are regarded as traditional forms of load management, intended to level the load curve of the electricity demands, as obtained after step 2 of the planning stage. A utility would find it easier to provide electricity in conditions where the load is as consistent as possible. Utilities in India face with severe difficulties to regulate its production in order to constantly follow the load-curve variations, and load shedding is the most simple and common way to manage the increased demand, under situations of inadequate supply. The utilities thus should set up programmes which help stabilize the load curve, in order to reduce operational costs and the costs of kWh production. Valley filling, on the other hand, has advantages of increasing the sales and thus, improving system load factor by building load in off-peak periods, enabling to compensate for the losses incurred during peak clipping.

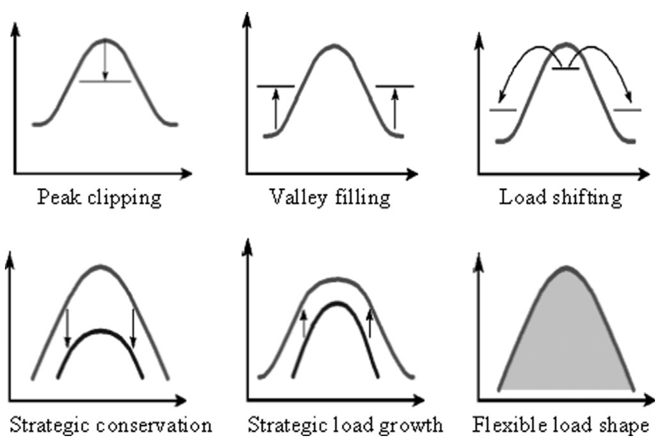


**Fig. 5.** Generic load shape objectives that are considered during DSM planning.

Strategic conservation, strategic load growth, and flexible load shape are the other three non-traditional load shape changing options which share a common objective of making the load curve profile as consistent as possible achieved through direct influence on the electricity market. Induction of CFL technologies, large scale availability of energy efficient motor, pump-sets are some of the examples of such objectives of load shape change in India.

India has peaks of equal significance occurring in the daytime and night time, along with a total different pattern of consumption in different end use sectors. During the daytime, the peak is due to the industrial, institutional, and business sectors whereas the evening peak is largely attributed to the residential sector. Such a situation demands the DSM programme to be designed that addresses all the types of the end users of different sectors; though such a programme would be comparatively costlier.

#### 2.1.5. Identify sources of financing

DSM measures require large investments in terms of monetary as well as non monetary resources which usually have alternative use. These investments need to be justified by the benefits so derived otherwise they can turn out to be costly to the society at large [22]. Utilities also require financing to cover administrative costs and cost sharing investments [45]. The types of innovative financing that can be used to encourage participants to undertake projects under a DSM programme include:

- Direct contracting by the utility.
- Performance contracting by the utility.
- Performance contracting by Energy Service Companies (ESCOs).
- Leasing.
- Participant self-financed savings re-investment.

Major sources of project financing can include:

- Energy Service Companies (ESCOs).
- Revolving funds (from a Lines or Public Benefit Charge).
- Self financing – recovery of costs through tariffs.
- Private equity, venture capital funds and project finance debt from nationalized Banks/Private Banks.
- Dedicated lines of credit or Special funds generated from the levy of additional charges to the end-users.
- Multilateral, bilateral and other international institutions/development agencies dedicated to promoting energy efficiency services.

**Table 2**
Load curve change objectives with respect to end use appliance.

| Load – curve modification objectives | End use appliances or technologies | | | | |
|---|---|---|---|---|---|
| | HVAC | Lightning | Refrigeration | Electric motors | Low load appliances (Fan, TV, mixing grinders, etc) |
| Peak clipping | ● | ■ | ■ | ● | ■ |
| Valley filling | – | – | – | – | – |
| Load shifting | ● | ■ | ■ | ● | ■ |
| Strategic conservation | ● | – | – | ■ | ■ |
| Strategic load growth | ■ | – | – | – | – |
| Flexible load shape | ■ | – | – | – | – |

● Strongly recommended.
■ Occasionally recommended.
– Not or rarely recommended.

Indian regulatory commissions play active role in arranging funds for utilities to implement DSM initiatives. Also the utilities are looking forward to adopt sound marketing strategies to attract private equity and other project finance loans from commercial and development banks.

*2.1.6. Programme selection and design*

After selection of load curve modification techniques, the next step in planning of a DSM strategy involves formulation of observations and a preliminary strategy for load-curve management. Such an action involves preparation of a grid, which would illustrate the relationship between the end-use and the objectives of load-curve modulations. For any particular load curve modification objective, the potential end-uses which are acceptable to the customers or which can be adjourned may be identified from a matrix. An example of such matrix developed considering the electricity consumption pattern of India is shown in Table 2.

This allows the planner to rapidly propose load-curve management strategies and programmes. Similarly, the planner should also examine and prepare similar grids for different sectors of electricity consumption, in order to identify the end-uses and measures that have the potential to contribute to DSM programme objectives.

Similarly, a matrix of the appropriate technologies for each of the end-uses is prepared, in order to meet the established load objectives. A particular technology can be totally appropriate for a particular type of end-use and not necessarily produce the desired effects on the load-curve modification objectives. It is often appropriate to consider the different technologies individually and then as a group in order to study their combined impact on the load curve. The effects of a particular option can sometimes reduce the effects of another type of technology. For instance, the use of an occupancy sensor to enable on-off control of the lightning system of the room could also reduce customer's interest in installing more energy-efficient lamps. On the other hand, certain technologies combined with others can noticeably increase the overall impact without causing any significant increase in the implementation costs.

*2.1.7. DSM cost – benefit analysis*

The basic purpose of conducting cost – benefit analysis of DSM programmes is to be able to choose the most efficient and viable option of all the available programmes, on the basis of their technical potential and viability. Different stakeholders, the consumer, the agency or power utility running the programme, and society at large as represented by a strategic planner or government, will have different benefits and costs of a DSM programme.

The direct benefits of a DSM programme are the number of kWh per year savings achieved and the peak demand reduction. The value of these savings to a consumer depends on the tariff (electricity price and demand charges). Possible benefits including maintenance and labor saving benefits associated with the efficient technology value to the power utility and to society at large depending on the “avoided” or long run marginal cost of new energy supply (e.g. a power plant and/or transmission line). This avoided cost is the energy cost for the next kW capacity added to the system. The avoided cost depends on whether the savings are at peak or off peak times (as measured by the coincidence factor), and whether excess capacity is available at that instance. All stakeholders benefit if these avoided energy costs escalate in real terms over time.

*2.1.7.1. Cost analysis.* A cost incurred on the consumer is given by:

$$CC = TC + FC - SC$$

SC can account for any contribution that the programme agency makes through financial support that may be in the form of a soft loan, support to the supplier to lower the price, or direct payment to the user

Cost incurred on the utility.

$$UC = TC + TrC$$

Technology costs are the incremental cost of the efficient technology implemented by the utility and transaction costs are the administrative and other costs of operating the DSM programme by the utility.

*Total Resource Costs* (*TRC*): The overall cost to society is simply the technology plus programme administrative costs. This is often called the Total Resource Cost. The sharing of the technology cost between the user and the DSM programme development organization does not affect the total cost, and financing charges are not normally considered in strategic planning [47].

Each DSM programme is evaluated as to its viability from different perspectives of society, utility, consumer, and in some specific cases, contractor (if used in the programme). Using estimates of the annual costs and benefits for each stakeholder, internal rate of return and net present value can be calculated. These measures allow a DSM programme to be compared both with power supply options and with other investment options. The cost of saved energy (per kWh) and peak demand reduction (per kW), are useful measures for comparing DSM with the supply options.

The costs and benefits used to estimate financial returns vary among the stakeholders and depend on additional programme characteristics such as cost sharing arrangements and lost revenue. Tax and other measures also affect financial returns. In addition, it is important to carry out rigorous sensitivity analysis to determine the switching values of important parameters such as participation rates, savings expected from each project, technology costs, programme costs and valuation of savings.

*2.1.8. Identify local socio-economic and environmental impacts*

DSM helps in reducing green house gas emissions, indirectly and thus, provides indirect economic and environmental benefits. For example, employment is created in the energy services industry and consumer savings are reinvested in other goods or services. Economic models such as the input/output model can be used to estimate these impacts. Indirect environmental impacts might include the benefits of accelerated removal of chlorofluorocarbons (CFCs) from air conditioners or establishing a disposal facility for used fluorescent lamps.

Though implementing DSM technologies have indirect environmental benefits, necessary attention has to be paid to the direct environmental impacts of DSM technologies. Possible direct impacts of adopting a DSM programme could include effects on indoor and outdoor air quality, deterioration of the ozone layer, and ground water quality [75,76]. As utilities adopt DSM programs, tools are required for evaluating these potential impacts.

Poorly designed or heedlessly implemented DSM practices such as breakage or improper handling of old fluorescent lighting equipment can cause exposure to mercury and Polychlorinated Biphenyls (PCBs) [77].

**Table 3**
Emission coefficients.

| **Type of fuel** | **Conversion efficiency (%)** | **Emission factor (kg/kWh)** | | | |
|---|---|---|---|---|---|
| | | *$CO_2$* | *$SO_x$* | *$NO_x$* | *Fly Ash* |
| Coal | 30 | 1.05 | 0.0039 | 0.0048 | 0.0004 |
| Fuel oil | 35 | 0.80 | 0.01 | 0.002 | 0.001 |
| Gas | 45 | 0.59 | | 0.0004 | 0.000 |

**Table 4**
Emissions after DSM programme implementation.

| Year | Energy requirement (TWh) | | | Emission reduction ($\times 10^3$ tonnes) | | | |
|---|---|---|---|---|---|---|---|
| | *Without DSM* | *With DSM* | *Savings* | $CO_2$ | $SO_x$ | $NO_x$ | *Fly ash* |
| 2000 | 670.0 | 626.5 | 43.5 | 34,423 | 101 | 153 | 137 |
| 2005 | 916.1 | 833.8 | 82.3 | 64,175 | 191 | 283 | 249 |
| 2010 | 1230.0 | 1116.7 | 113.1 | 87,688 | 264 | 384 | 337 |

Adopting DSM practices not only reduce electricity consumption, but also reduce the resulting pollutant levels [78]. By taking the conversion efficiency (of Table 3), estimated reductions over the period 2000–2010 are presented in Table 4.

EIA of various DSM practices, such as use of electric arc furnaces, vapor absorption refrigeration systems, good housekeeping practices, industrial cogeneration, energy efficient motors and lighting, adopted in India [19] have been studied by Reddy and Parikh [78]. Net benefit is determined by calculating the avoided emissions by multiplying each emission coefficient of table with the avoided generation, as shown in Table 4.

Although a variety of environmental problems can be raised in connection with DSM, these problems can generally be minimized or eliminated through careful program design and technology choices. In every case in which quantitative comparison is possible, the direct environmental impacts of well designed DSM programs are much smaller (often by one or more orders of magnitude) than the avoided impacts of electricity generation [79]. Regardless of the magnitude of the environmental impacts of a particular DSM programme, Environmental Impact Assessment (EIA) is necessary to be deployed to DSM programme development.

#### 2.1.9. *Programme implementation plan*

Having prepared the complete plan for implementing a particular DSM programme, effective implementation of the same requires an active DSM cell, established within a power utility to manage its implementation. According to electricity regulations formulated by various states and central agencies of India, for effective execution of DSM programmes, formulation of DSM cell is a mandatory.

DSM cell established within the utility is responsible for the standard contracting and bidding procedures, marketing and promotion of the developed DSM programme, scheduling the activities to achieve yearly targets. The cell is also responsible for the preparation of budget and expenditure plan.

First DSM programme in India was launched in 1999 in which a DSM cell was set up by the Ahmedabad Electricity Company (AEC) with responsibilities of developing load research data, screening alternative energy efficiency measures and implementing some of those measures through the involvement of ESCOs. DSM cells with almost similar roles and responsibilities were established in states of Tamil Nadu, Rajasthan, Maharashtra, and Gujarat. Further, Maharashtra Electricity Regulatory Commission (MERC) entered into a Memorandum of Understanding (MOU) with the California Energy Commission (CEC), California Public Utilities Commission (CPUC) and Lawrence Berkeley National Laboratory (LBNL) of the United States, to develop its own capacity and also that of the distribution utilities in the areas of load research, integrated resource planning, demand response, etc [61].

#### 2.1.10. *Monitoring and evaluation*

Energy Measurement and Verification (M&V) is defined as the process of measuring and verifying both energy and cost savings produced as a result of the implementation of DSM measures [43]. The need for cost effective M&V has become critical in India because of reduced government funding on energy conservation measures and the increased funding of these programmes by the private sector through energy savings performance contract and demand side management (DSM). Effective M&V is the only means of determining the performance of the contractor, and to check DSM measures are generating the expected level of cost savings. This process will determine how much the government has saved, and how much the government must pay the contractor.

Energy or demand savings are determined by comparing measured energy use or demand before and after implementation of energy savings programme [46]. In general

$$\text{Energy savings} = \text{Base year energy use} - \text{post retrofit energy use} \pm \text{adjustments}$$

In the above equation, 'adjustments' brings energy use in any two time periods under the same set of conditions. Conditions commonly affecting energy use are weather, occupancy, plant throughput, and equipment operations required by these conditions. Adjustments may be positive or negative. Adjustments are derived from identifiable physical facts. The adjustments are made either routinely such as for weather changes, or if occupants are added to the space, or increased usage of electrical equipments for increasing output. Adjustments are commonly made to restate base year energy use under post-retrofit conditions.

## 3. DSM regulations and policies of India

Policies and regulations with a legal framework prevail in a nation with the help of institutional structures. Legislation relevant to the activities of the power sector provide the institutions to derive their responsibilities as well as powers and carry out their associative functions. Analyzing the relevant legal and policy frameworks, provisions are necessary for identification of institutional barriers.

Distribution utilities in India by large are government owned which supply electricity in a regulated environment but are influenced to go for cross subsidies and social framework considerations which in turn are indirectly stimulated by the political system. Large scale DSM programme implementation in India require large technical as well as financial investment and a high level of monitoring and governance system. The net benefits of DSM are the marginal cost of power and the tariff collection from sale of power to consumers [72]. Utilities are required to cover their costs for debt payments, salaries and managing assets through tariffs. Utilities tend to look for current benefits rather than having long term benefits through investments in DSM technologies [73]. Due to uncertainty and volatility in demand, fuel costs, load shedding schedules etc it becomes very difficult for the utilities and regulators to monitor and verify the savings resulting from the DSM programs [74].

DSM programmes in India are largely focused on peak load reduction. However, utilities earn significant revenue by way of supplying power to the industries during the peak hours as tariff for such categories is linked to the time of use and are thus high. No such provisions are available for other sectors like commercial, domestic, railways, etc. Agriculture and small scale industries are heavily subsidized. Utility's perception of losing revenue by way of DSM implementation is one of the reasons for their inactive participation in DSM activities in India.

Consumer awareness is the simplest activity of DSM by any of the stakeholder involved. Planning and implementation of such a basic DSM programme costs the utility. The cost plus tariff determination does not necessarily have adequate inducement to utilities for carrying out such measures. In India, utilities do not get induced to implement DSM measures as they are neither directly related to their core business of electricity supply nor mandated under the legal framework. Therefore, major focus in

India has been on capacity addition rather than implementing DSM programmes.

Keeping in view with such limitations, India has developed policies to support DSM and energy efficiency programmes [47]. However, such policies need to be revised and there is a need to develop regulatory mechanism which incentivizes utilities to take up DSM programmes on a larger scale. Inclusion of DSM related expenditure as a part of the Annual Revenue Requirement (ARR); development of a simple mechanism to allow recovery of DSM related costs through tariffs; provision of a suitable incentive mechanism to allow the utility to earn additional return on equity for procurement of DSM resources in place of supply side resources along with higher incremental return on equity for investments in DSM programmes in subsidizing categories of commercial and industrial sector are proposed as a part of regulatory framework to encourage utilities in India to undertake and implement DSM initiatives [48]. Utilities may also be encouraged to develop peak load saving programmes so that overall power purchase cost to the utility decreases. Utilities may be allowed to retain percentage of such saving.

### 3.1. National electricity policy

The National Electricity Policy of India came into notification on 12th February 2005. It provides direction to the evolution of the power sector within the ambit of the Indian Electricity Act 2003 [49,50]. Various other issues like rural electrification, capacity additions, energy conservation, promotion of renewable energy, environmental issues, etc have been listed in the policy. In order to minimize the overall requirement, energy conservation and demand side management (DSM) is being accorded high priority. As per this policy the periodic energy audits have been made compulsory for power intensive industries. Energy conservation measures are being adopted in all of government owned buildings for which saving potential has been estimated to be about 30% energy. Solar water heating systems and solar passive architecture have been recognized to contribute significantly to this effort [49]. Policy also emphasizes on labeling and standardizing of appliances for voluntary and self-regulating initiatives; on the promotion of the high efficiency pump sets and the water delivery system in agricultural sector and adoption of energy efficient technologies and energy audits in industrial sector. Energy efficient lighting technologies are also to be adopted in industries, commercial and domestic establishments [50]. To reduce the requirements for capacity additions, the policy promotes adoption of suitable load management techniques like differential tariff structure for peak and off peak supply and metering arrangements (Time of Day metering) with regulatory commissions ensuring adherence to energy efficiency standards by utilities. A action plan has been developed, to enlarge the role of Energy Service Companies (ESCOs), for effective implementation of energy conservation measures [64].

### 3.2. Integrated energy policy

Currently, consumers of electricity in India pay one of the highest prices for energy in purchasing power parity terms [22]. This has eroded the competitiveness of many sectors of the economy. India currently faces the challenge to ensure adequate supply of electricity at the least possible cost. Electrification of rural areas is one another important challenge as it is necessary to provide clean and convenient electricity to the poor even when they cannot fully pay for it, as it is critical to their well-being. Therein lays the significance of an effective and comprehensive energy policy. An Expert Committee has formulated an Integrated Energy Policy in 2006, linked with sustainable development that covers all sources of energy and addresses all aspects of energy use and supply including energy security, access and availability, affordability and pricing, as well as efficiency and environmental concerns [61]. The integrated energy policy identified DSM as one of the important options for energy planning. However, as of date, very little experience exists in India regarding development, implementation and monitoring of the DSM programmes.

## 4. Barriers and challenges to DSM in India

Utilization of electricity has been inefficient which has led to high potential for DSM in India. There are a number of barriers that are hampering the implementation of DSM programmes and for effective realization of DSM potential in India such barriers need to be identified and overcome. In order to study the barriers, they have been categorized as follows.

### 4.1. Market barriers

Market penetration of DSM programmes is hampered by several barriers in India that are influenced by prices, financing, market structure, institutions, the provision of information and social, cultural and behavioral factors. Market barriers are defined as characteristics of the market for an energy-related product, service or practice that help in understanding of the gap between the actual level of investment in, or practice of energy efficiency and the increased level that would appear to be cost-beneficial for the consumer [51]. Some of the most significant market barriers that are observed in India include:

- Lack of technical ability: there is lack of proper information in the sector specific energy use patterns characterized by insufficient technology specific engineering data, and a scarcity of information about the availability of energy efficient equipment and practices. In order to assess costs and benefits of the selected DSM technology, the level of technical training related to energy consumption is low in India [62]. Due to increased focus on supply side such as solar and wind, DSM experts experienced particularly with that of programme design, implementation, evaluation, monitoring and verification skills are lacking in India.
- Lack of awareness: large population of the consumers of electricity in India lack easy access to information on DSM. As a result of which, there is uncertainty about the quality of new and efficient products and technologies of DSM. BEE has taken up the initiative and launched a number of programmes to market the concept DSM among the consumers of different sectors, but this is still at nascent stage. Lack of trust, limited product warranty and lack of credibility about a warranty are some other barriers for implementing a sound DSM programme [62].
- India lacks availability of sufficient capital and/or access to financing where investment selection criteria for new equipment and the structure of financing mechanisms give priority to supply-side solutions to energy shortfalls over demand-side options.
- Subsidized electricity pricing: sectors like agriculture receive heavily subsidized electricity due to which DSM technologies are no longer cost effective when compared with the price of energy supply.

### 4.2. Institutional barriers

The institutional barriers refer to conditions created by the nature and scope of interventions by government and regulatory agencies to influence the marketplace according to public policy objectives and budgets [52].

- Inappropriate policies and programmes of DSM lacking adequate legal and regulatory backing to be pursued by utilities or other entities is a major barrier in India [62]. Failure of the regulators and utilities in recognizing the benefits of adoption of DSM programmes to meet demand in one of the possible reasons.
- Lack of fiscal incentives for DSM investments.
- Lack of high energy performance standards and deficiencies in their enforcement.
- Lack of continuity in institutional energy efficiency incentive programmes.
- Imposition of taxes and tariffs on imported manufactured goods, including energy efficient equipment.

### 4.3. Challenges

In India, electricity is a concurrent subject i.e., a matter on which both the central and state governments have specific, and overlapping powers, which complicates technical and investment related decisions. India faces many challenges for implementing a effective DSM programme on a large scale. Some of the notable challenges are described below.

#### 4.3.1. Poor financial status of state distribution utilities

Most of the distribution companies in India are owned by its respective state governments. There is always pressure to keep the tariffs low for politically influenced sectors like agriculture and small industries. Some service sectors like municipalities do not pay the consumption charges due to financial reasons but receive reliable supply of electricity. As a result of which there is low recovery of revenues and thus most distribution companies suffer heavy losses. This leaves the utilities with hardly any funds to upgrade their distribution networks. Hence, the states in general look toward the central government to provide funds and technical support for strengthening the distribution system.

#### 4.3.2. Non-involvement of private utilities

The Indian distribution system has been suffering from problems of theft, weak infrastructure, politically motivated decision-making, and lack of information technologies to process data. Many private organizations shy away from being involved in the distribution business due to lack of revenue collections or lack of clarity in profits owing to the above mentioned reasons.

#### 4.3.3. Limited sources of funding

Currently, India is at its nascent stage of implementation of DSM programmes and many of the DSM projects are being implemented as pilots in various states. The funds for these projects are mostly provided by the central government or external grants.

#### 4.3.4. Business case challenges

The needs and backlogs in Indian power sector are not necessarily the same as those in advanced industrialized countries. Generally, not all DSM technologies are equally relevant worldwide. In India, the really useful technologies will be those that help constrain peak demand and peak-load growth at reasonable costs while cutting losses [53].

#### 4.3.5. Unique expectations from the concept of DSM

India has altogether a completely different way of consumption of electricity at the end use sector and many solutions adopted in highly industrialized countries will not work on a large scale in India. Hence, it is the government which should lead the way in implementation of DSM technology, showcasing its benefits in loss reduction, integration of renewable energy and energy conservation measures, better power quality, and efficient utilization of power assets. India and other countries at a similar developmental stage are not worried about labor costs associated with reading meters as much as the accuracy of billing. India is more concerned about the burgeoning demand for power and its access by the masses. India urgently needs to provide an efficient means to address these for fast and inclusive growth of the economy as a whole.

#### 4.3.6. GAP at the implementation level

India already has devised several policies toward strengthening the distribution infrastructure. However, a lack of support at implementation levels has resulted in far less than satisfactory implementation of the policies. The primary reasons for failure at the implementation levels are lack of incentive for the implementing parties, lack of adequate skilled workers, lack of transparency of the systems, and lack of political will. Utility driven large scale DSM programmes have substantial impacts on consumer tariffs [73]. Due to political sensitivity, regulators in India are cautious about increasing the tariff, even if an increase is needed because of higher cost of fuel and/or investment in DSM and new infrastructure [74]. The split goal between political priority and commercial interest often creates confusion in the roles and focuses of the distribution utilities.

The formulated policies are expected to be implemented by the distribution utilities which are mostly owned by the state governments, which sometimes defer from the central government. Most policies lack incentives to motivate workers toward the policies or any disincentives in case they failed to do the needful [42]. The lack of control over the implementing counterparty has been the primary reason for weakening of policy implementation in the past.

Successful implementations of DSM programmes in India require continued support political leadership from policy makers. Consistent political messages and effective public communication are crucial to obtain the public support for the necessary DSM programme implementation, which is not practiced on a large scale in India.

**Table 5**
Typical DSM programmes of UK.

| Programmes | Customer | Main target | Fuel | New/Retrofit |
|---|---|---|---|---|
| Carbon Emission Reduction Target (CERT) | D | EE – BL&A | All | Retrofit |
| Reduced VAT on energy saving materials | D | EE – BL&A | All | Retrofit |
| Negotiated energy agreements | B | EE – BL&A | All | Retrofit |
| Energy efficiency loans | B | EE – BL&A | All | Retrofit |
| Commit to save your 20% | D | EE – BC&I | All | – |
| Carbon Management | B | EE – BC&I | All | – |
| Economy 7 | B/D | PD | Electricity | – |

B: Business consumers.
D: Domestic consumers.

**Table 6**
Typical DSM programmes of USA.

| Programmes | Customer | Main target | Fuel | New/Retrofit |
|---|---|---|---|---|
| Residential energy services: retail efficient products | D | EE – BL&A | Electricity | Both |
| Residential new construction | D | EE – BL&A, BC&I | All | New |
| Customer credit program | B | EE – BL&A, BC&I | All | Both |
| Existing business facilities assistance | B | EE – BL&A | All | Retrofit |
| Austin energy power partner | D/B | PD | Electricity | – |
| California statewide pricing pilot | D/B | PD | Electricity | – |

**Table 7**
Comparison of DSM programmes of India with US and UK.

| DSM Programme | India | USA | UK |
|---|---|---|---|
| Energy-efficient motors & variable-speed drivers | PI | MI | PI |
| Time-of-day/Time-of-use tariff | PI | MI | PI |
| Compact fluorescent lamps | MI | MI | PI |
| High efficiency fans and pumps | NI | PI | PI |
| power factor improvement techniques | PI | MI | PI |
| Industrial co-generation | PI | MI | MI |
| Peak demand reduction | NI | MI | MI |
| Advanced metering infrastructure – residential | NI | PI | NI |
| Advanced metering infrastructure – industrial | PI | PI | PI |
| Distributed Generation | NI | NI | PI |
| Power quality management | NI | MI | MI |

MI: majorly implemented.
PI: partially implemented.
NI: not/negligible implementation.

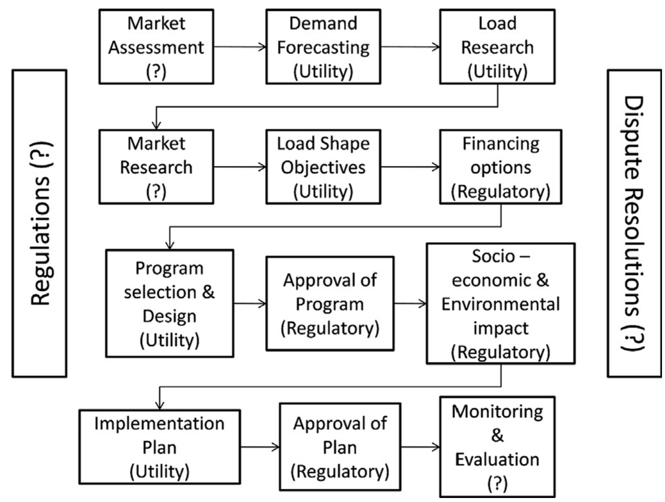


**Fig. 6.** Defects in DSM action plan formulated for utilities in India.

## 5. Comparison of DSM programmes developed by USA, UK and India

A brief overview of typical DSM programmes developed in USA and UK is presented here. All the programmes are assessed against the following objectives [65,69]:

(1) Implementation of energy efficiency in building, lighting and/or appliance improvements (EE – BL&A).
(2) Energy efficiency through behavioral change and/or improved information (EE – BC&I).
(3) Peak Demand Reduction (PDR) programmes.

Some of the programmes have multiple as indicated in the Tables 5 and 6. Additional information is also provided on the fuel that is saved by each of the programmes.

### *5.1. DSM programmes of UK*

Typical DSM programmes of UK are presented in Table 5. Mandatory standards (labeling) of appliances, lighting and insulation have been the area of largest opportunity for domestic consumers [65,66]. Financial incentives, loans for investment, audits, and awareness among consumers have been major areas for industrial consumers [67,68].

### *5.2. DSM programmes of USA*

A summary of the DSM programmes developed by USA is presented in Table 6. Financial incentives for high tension consumers, smart metering and direct load control technologies have been the successful areas for peak demand reduction [69]. The most common programmes for commercial and domestic customers were aimed at deployment of energy efficient equipment [6].

Behavioral change and improving availability of information available to consumers have become increasingly important in the last few years for making informed decisions regarding potential energy efficiency opportunities [70,71].

### *5.3. Comparison with India*

The most common target areas for domestic energy efficiency in U.S. and UK were lighting and insulation programmes. Such programmes achieve carbon savings in relation to cost but many of the insulation programmes constituted a more significant investment. However, the lighting programmes were general and available to all customers, sometimes for example using discount vouchers for purchase of compact fluorescent light bulbs (CFLs). Some of the programmes in terms of reducing energy consumption by improving the energy efficiency of appliances have resulted in voluntary or mandatory adoption of energy-efficiency standards by manufacturers. Such programmes are only effective if the agency/country setting the standards has sufficient market power/influence to persuade manufacturers to change the design of their products which is unlike India.

A comparison of typical DSM programmes of India with USA and UK are presented in Table 7.

## 6. Discussions and recommendations

Implementation of DSM measures in India has only been sporadic and large scale implementation plan is still unavailable. A complete holistic view is still lacking on design, development and implementation of DSM programmes, though BEE has developed a complete set of action plan for utility driven DSM programmes. In order to address issues of global warming and climate change, there is a revived boost for implementing DSM on a large scale in India.

A comprehensive review of the action plan developed by India for implementation of a particular DSM programme, carried out in the current study is shown in Fig. 6 along with the institutions currently responsible for the functionalities of the DSM framework. Consequently, activities of the action plan that are not being exercised by any of the organizations engaged in DSM have been identified. Activities such as current electricity market, EM&V, market research plan, monitoring and reporting, etc. have not yet been undertaken by any of the organizations engaged in EE or DSM in India. Identifying and stipulating organizations with the role of above mentioned activities is necessary. Also, Lack of capacity within the institutions associated with DSM has been prohibiting deployment of DSM activities on a large scale. Identification of the pre requisites for building up of the organization capacity against their expected roles is necessary.

Fig. 6 indicates the limitations in institutional framework as well as in legal & policy framework of the proposed action plan for DSM in India. Deficiencies include absence of clear mandate to the regulatory commissions to ensure development and implementation of DSM programmes, absence of requirement for distribution utilities to take up DSM measures, absence of policy regulations for proper planning and implementation of DSM activities. As per EC Act 2001, every state of India has to develop a State Designated Agency (SDA) bearing the responsibilities of preparing an energy conservation plan and also looking after its implementation. But, there has been a lack of coordination between SDAs, the distribution utilities and the regulators which has been one of the major reasons for non deployment of large scale DSM programmes in India.

## 7. Conclusions

Electricity is one basic infrastructural requirement, essential for the socio-economic development of India. Rising demand for electric power in India has given rise to challenges of addition of installed capacity and expansion of current transmission and distribution infrastructure. Generating capacity for electric power in India has increased steadily over the years but still is lesser than that of increased demand for electric power. This gives high possibilities of implementing of DSM activities. Also, relatively low efficient utilization and consumption of electricity by the consumers in India provides for a significant scope for DSM to contribute to increasing the efficiency of the system investment.

A very important part of DSM activity is formulation of an action plan for implementing a DSM programme. The paper has presented a detailed DSM programme planning and implementation strategy formulated by India. Deficits existing in the action plan framed by India have been illustrated. Indian DSM industry still at a nascent stage and has high potential for energy savings across various categories of consumers. Most of the projects implemented by the utilities are at pilot level trying to establish a market and reduce the uncertainty in energy savings. India has mainly utility operated and only a few government operated DSM programmes in planning phase. Implementation of such programmes requires time and resources. Such strategies differ from that of the western developed countries, as in India price and political factors matter a lot.

Barriers and challenges currently being faced by the various stakeholders of a DSM programme are also presented. Many programme and policy alternatives exist for implementing DSM techniques. Utility driven, government driven DSM programmes, regulations, and standards are some of the alternatives. Each of these has a significant role to play. Also, utility and non utility driven programmes can work together, and such collaboration can help in overcoming the barriers.

Looking ahead in the coming decade, leadership by state and local governments, ministry of power and its subsidiaries, and financial institutions is crucial to create change in India's electricity market towards cost-saving, energy efficient and state-of-the-art technologies. DSM has an important role in achieving the energy efficiency and energy conservation targets and thus, is a crucial element in the quest of sustainable energy future of India. Dealing with DSM requires careful selection of planning and implementation strategy along with state of art technologies. The steps involved in the action plan are not permanent as the process of DSM programme planning is dynamic in nature and depends upon the specificity of the situation and needs of the utility.

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